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(54) SHAFT LOCKING COUPLINGS FOR SUBMERSIBLE PUMP ASSEMBLIES

(76) Inventors: **John J. Mack**, Tulsa, OK (US); **Earl B. Brookbank**, Claremone, OK (US)

Correspondence Address:
James E. Bradley
BRACEWELL & PATTERSON, LLP
P.O. Box 61389
Houston, TX 77208-1389 (US)

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(57) **ABSTRACT**

An electrical submersible pump assembly has first and second modular component sections, each of the sections having an outer housing and an inner shaft member. A coupling sleeve having a bore is disposed between the modular component sections and receives the shaft member of each of the component sections. The bore of the coupling sleeve and the shaft members having mating radial load transmitting shoulders for transmitting torque. An axial load transmitting shoulder is affixed to the shaft member of the first modular component section and located in the bore of the coupling sleeve. A locking element is carried by the shaft member of the second modular section and engages the axial load transmitting shoulder to secure the shaft members to one another for transferring axial tension from one of the shaft members to the other.

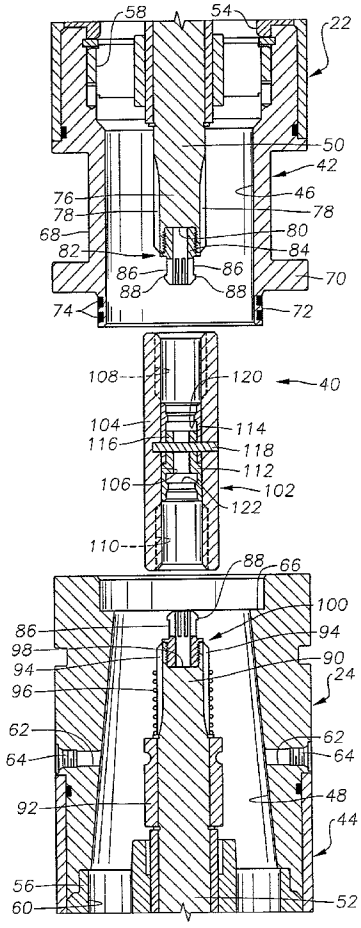


Fig. 1

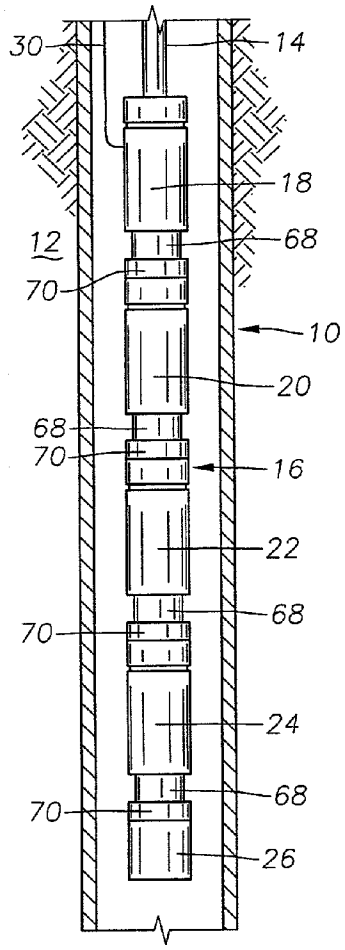

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Fig. 2

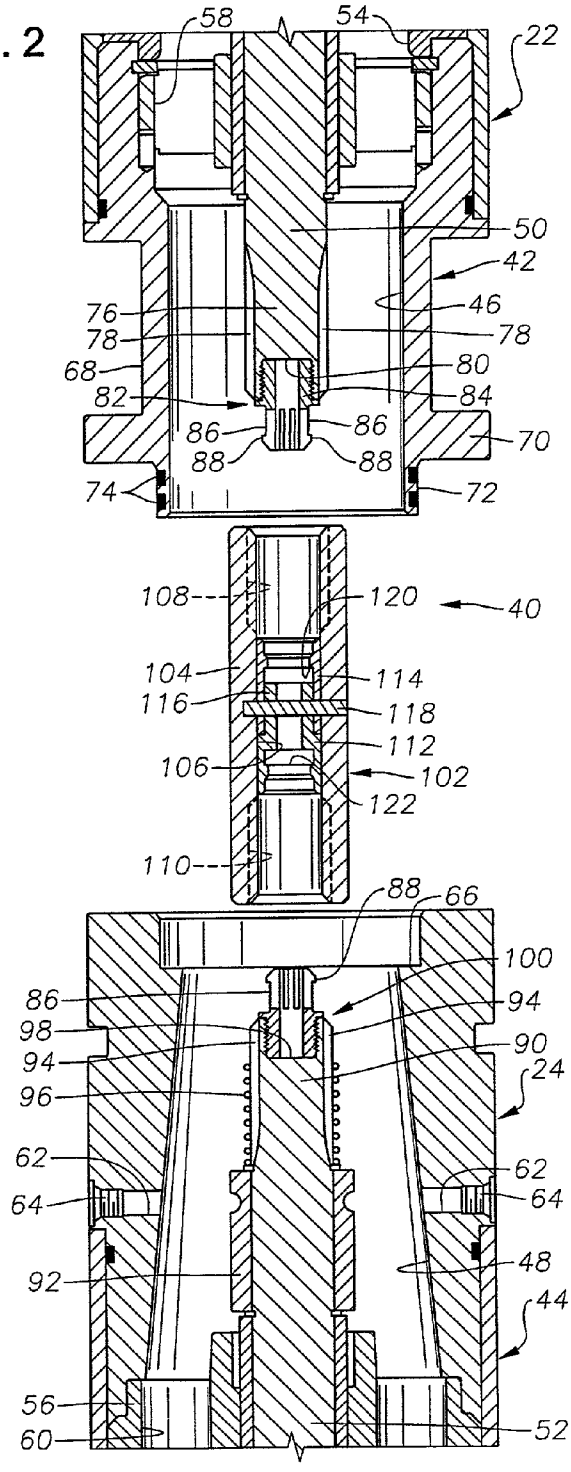

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Fig. 3

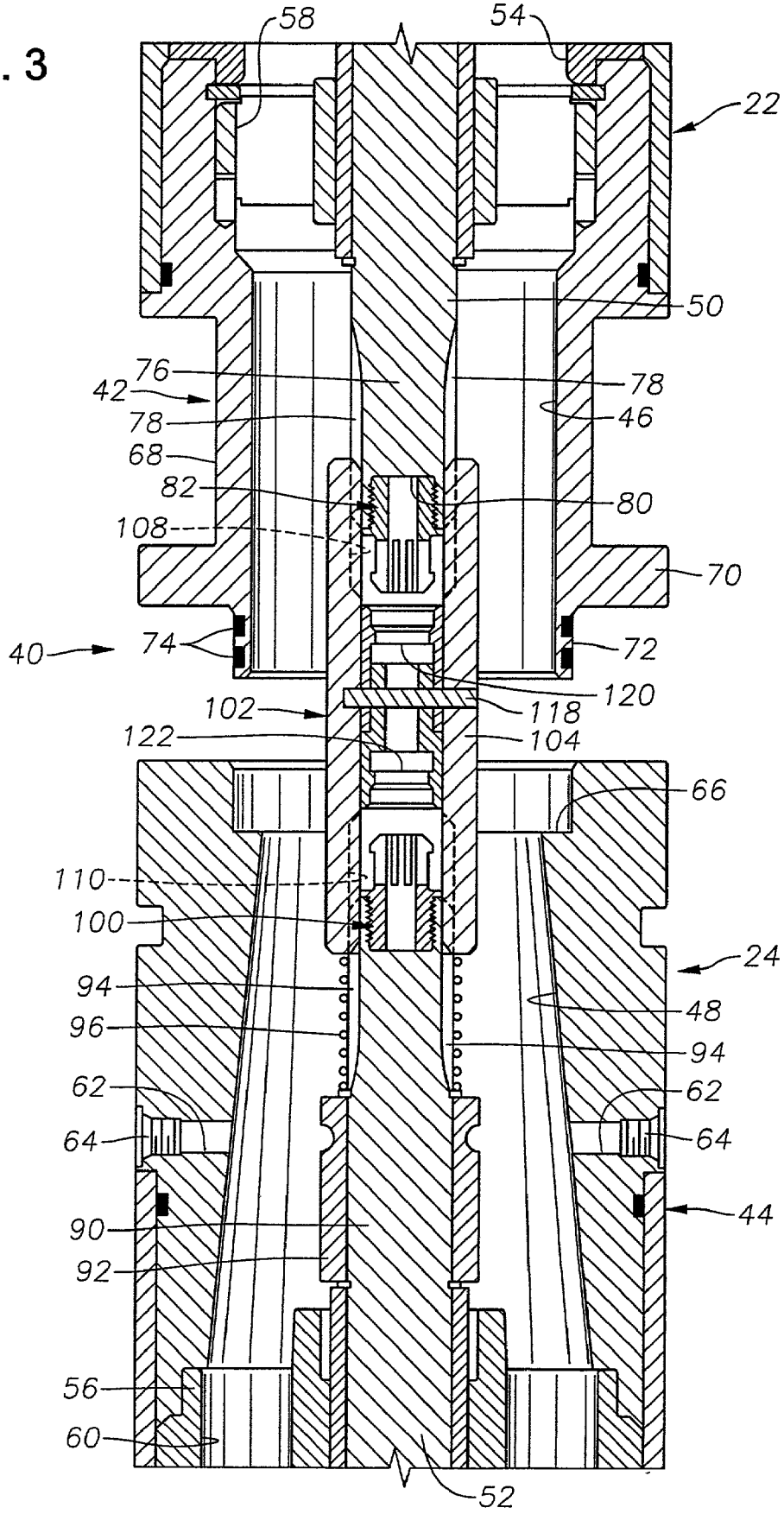

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Fig. 4

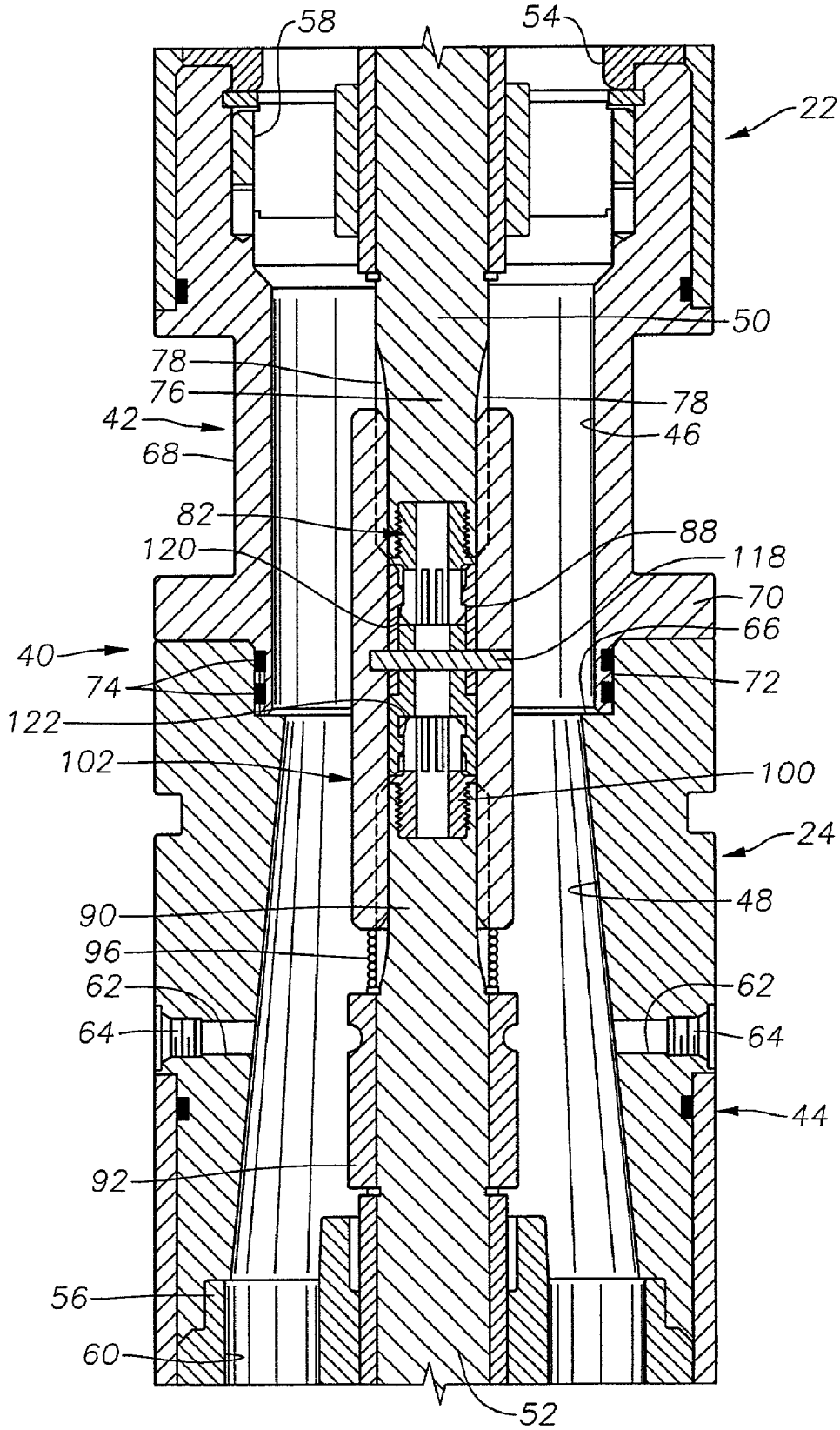

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Fig. 5

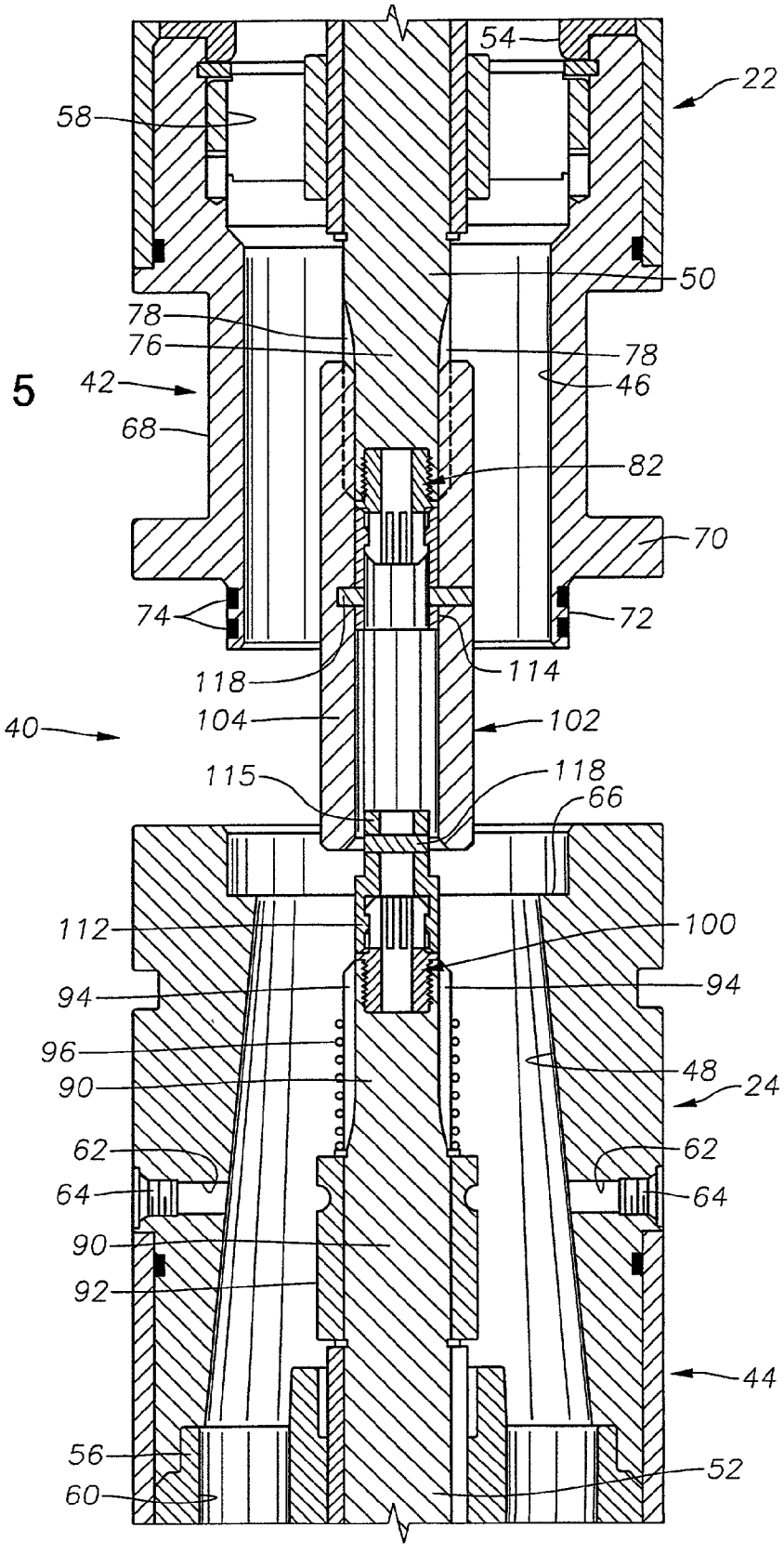

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Fig. 6

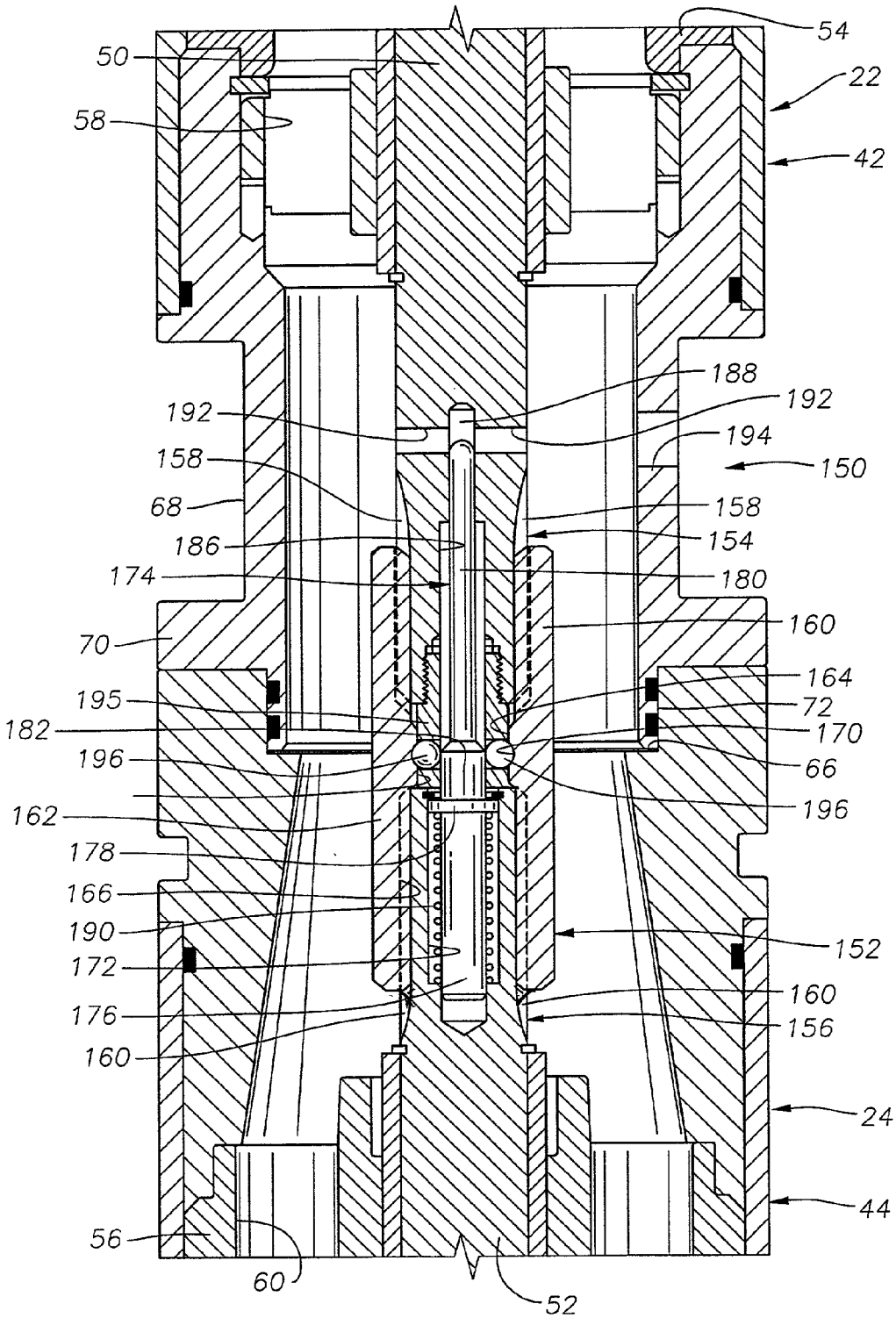

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Fig. 7

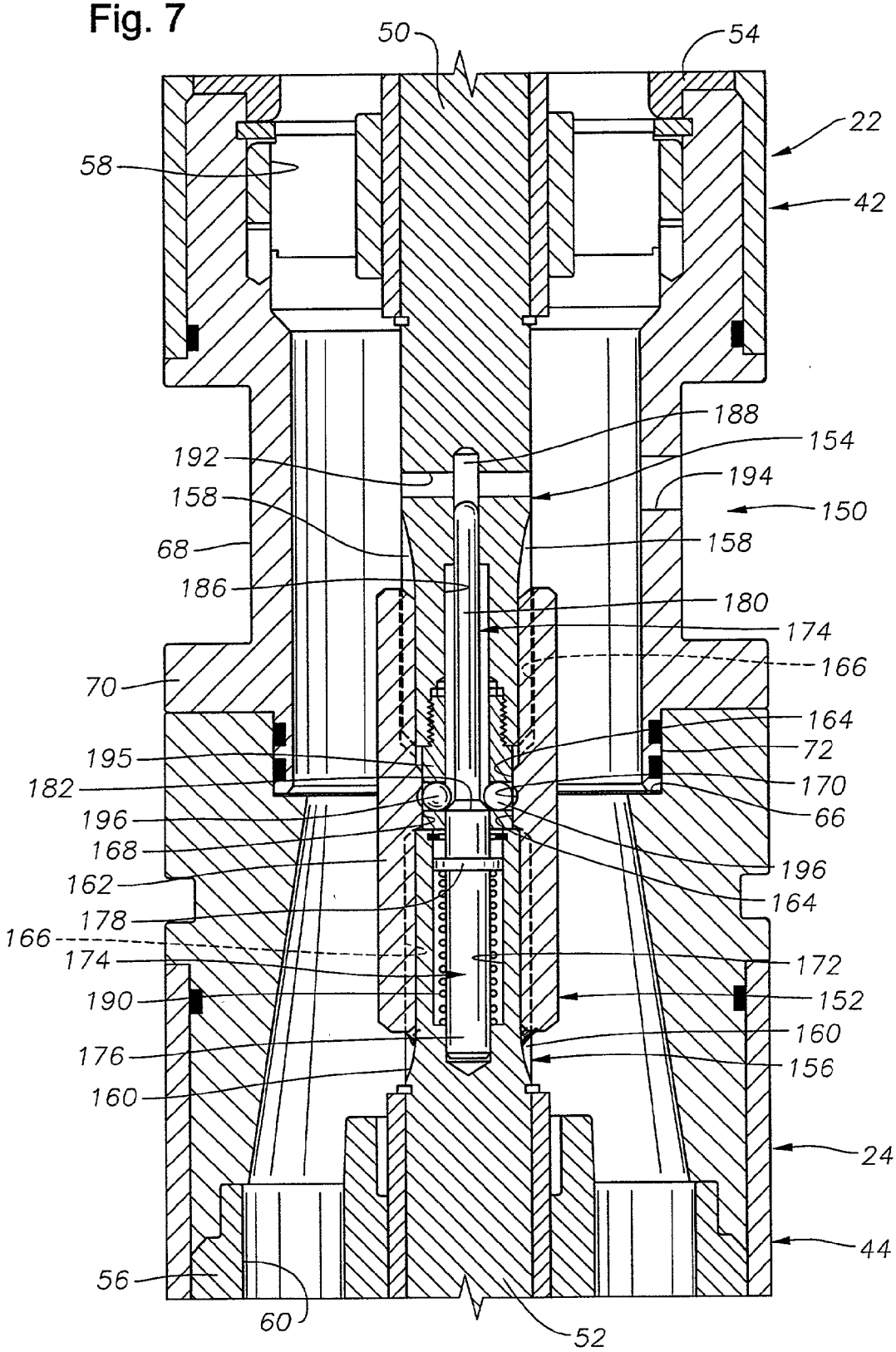

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Fig. 8

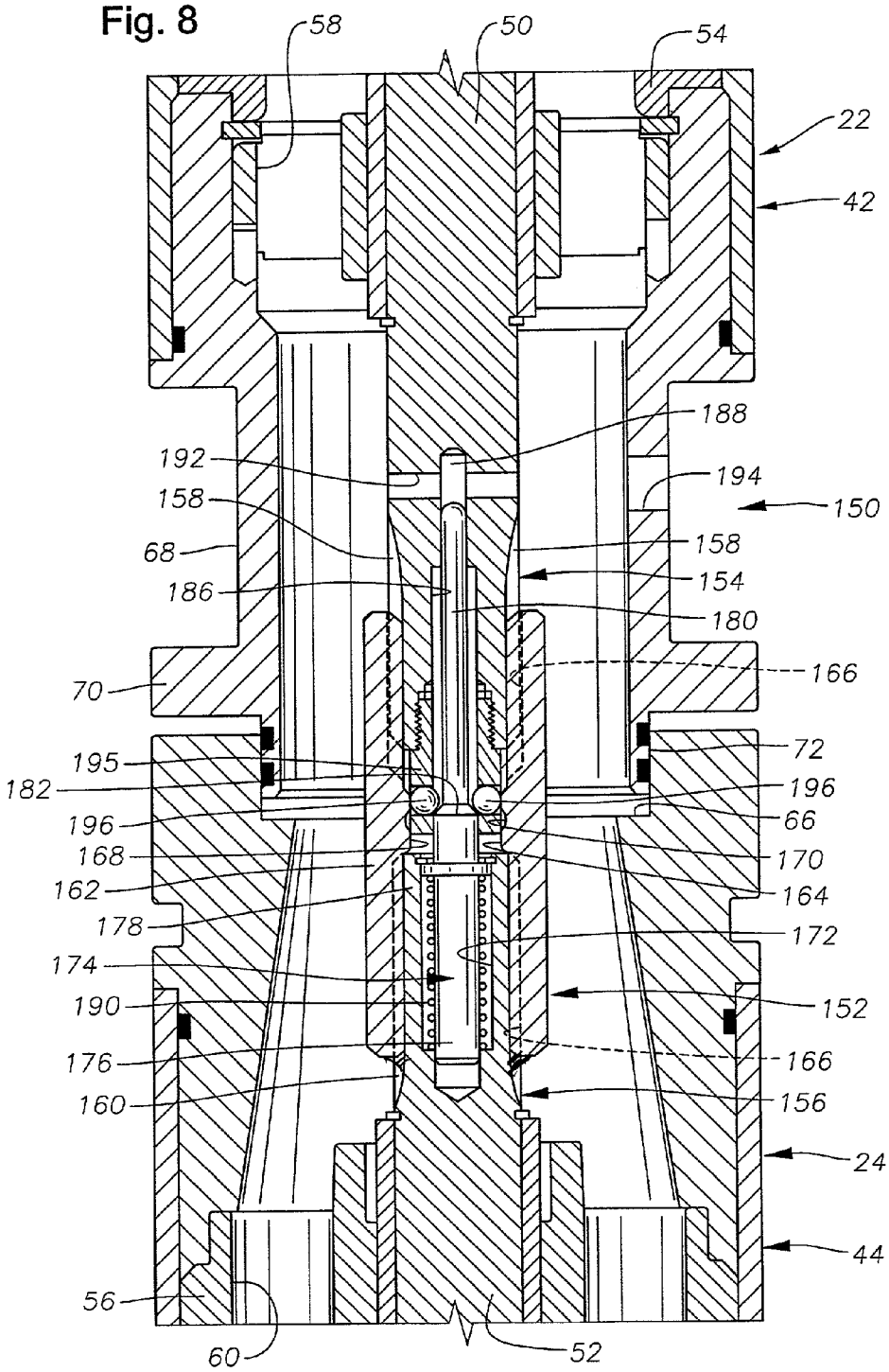

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Fig. 9

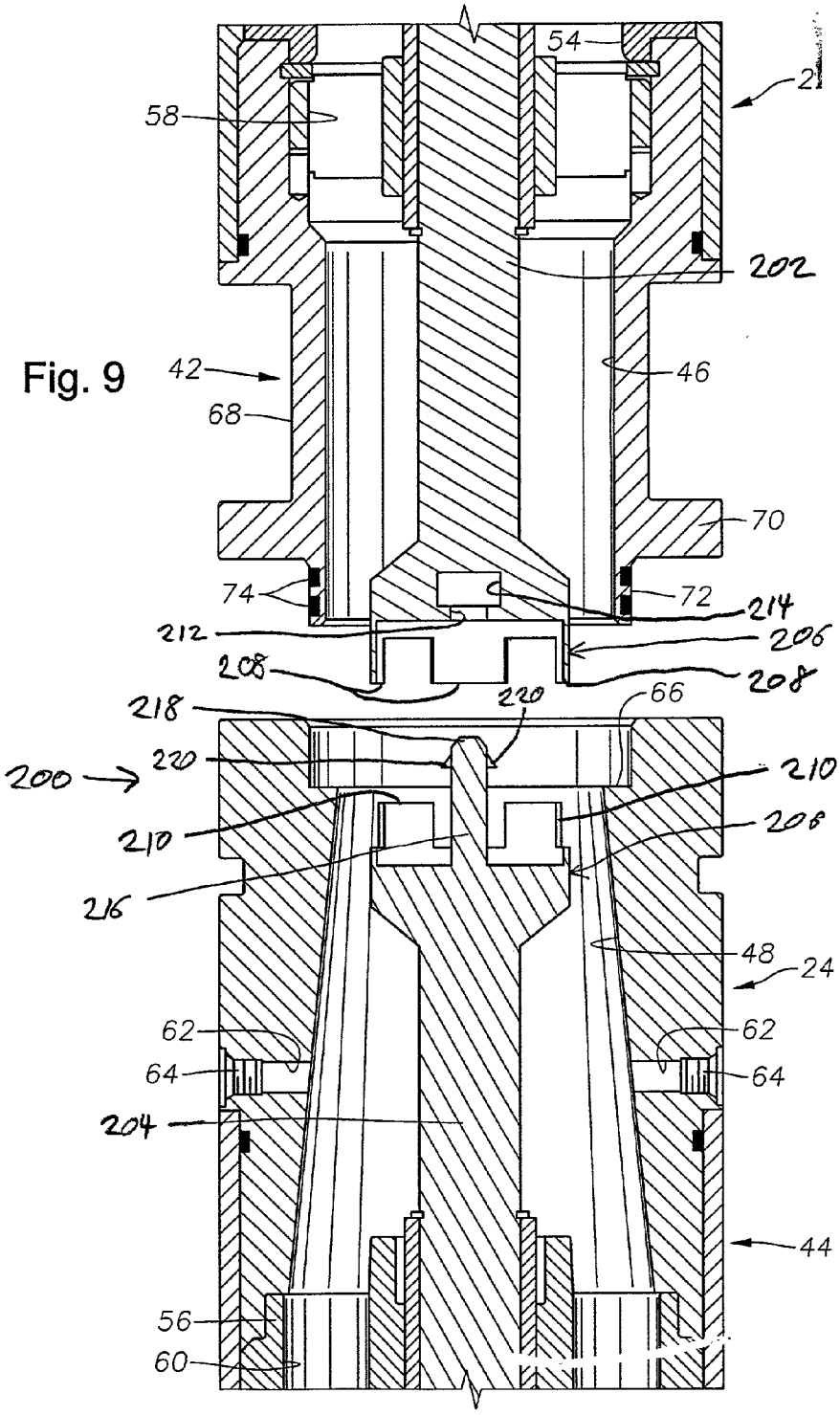

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Fig. 10

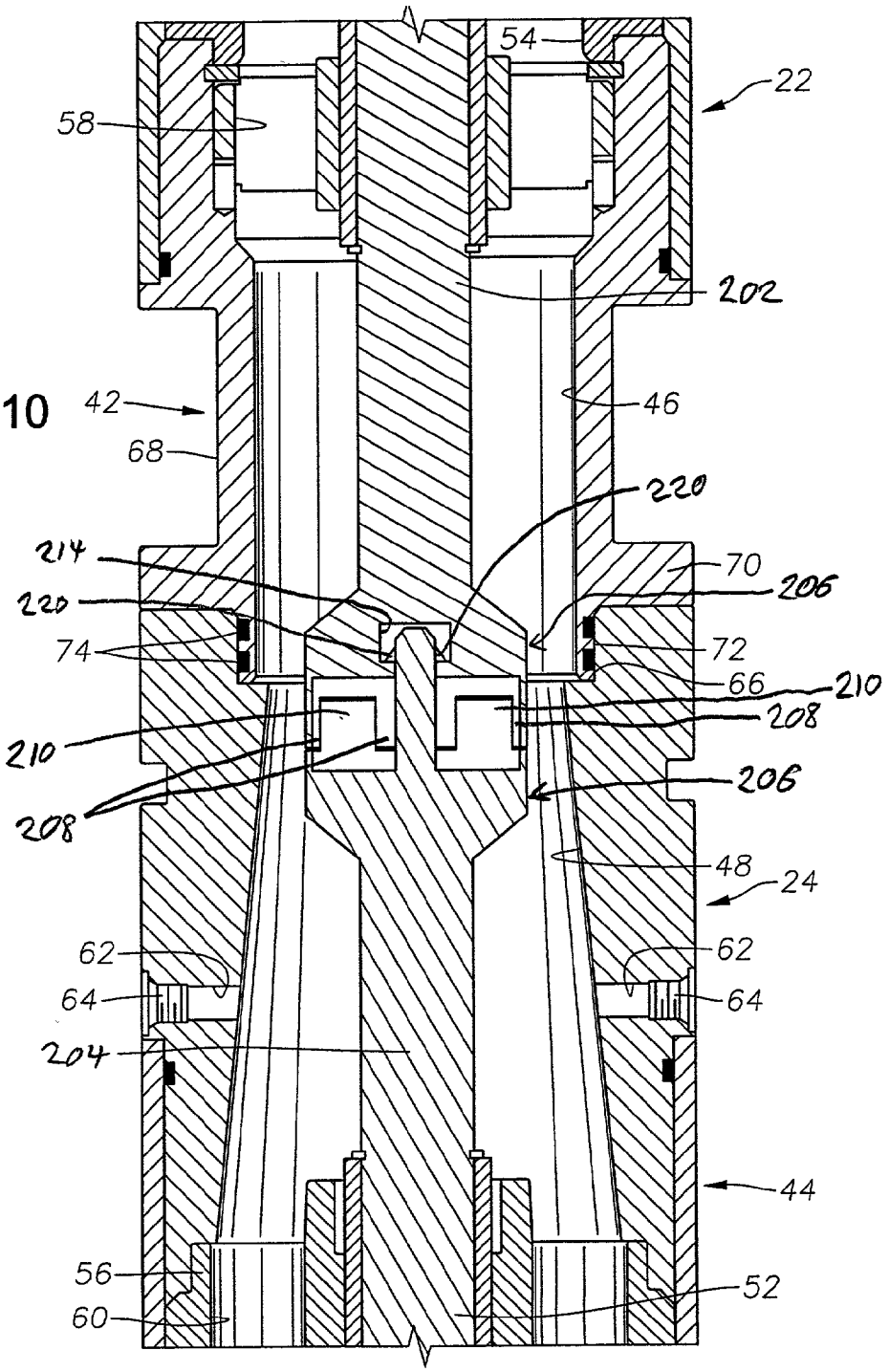

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Fig. 11

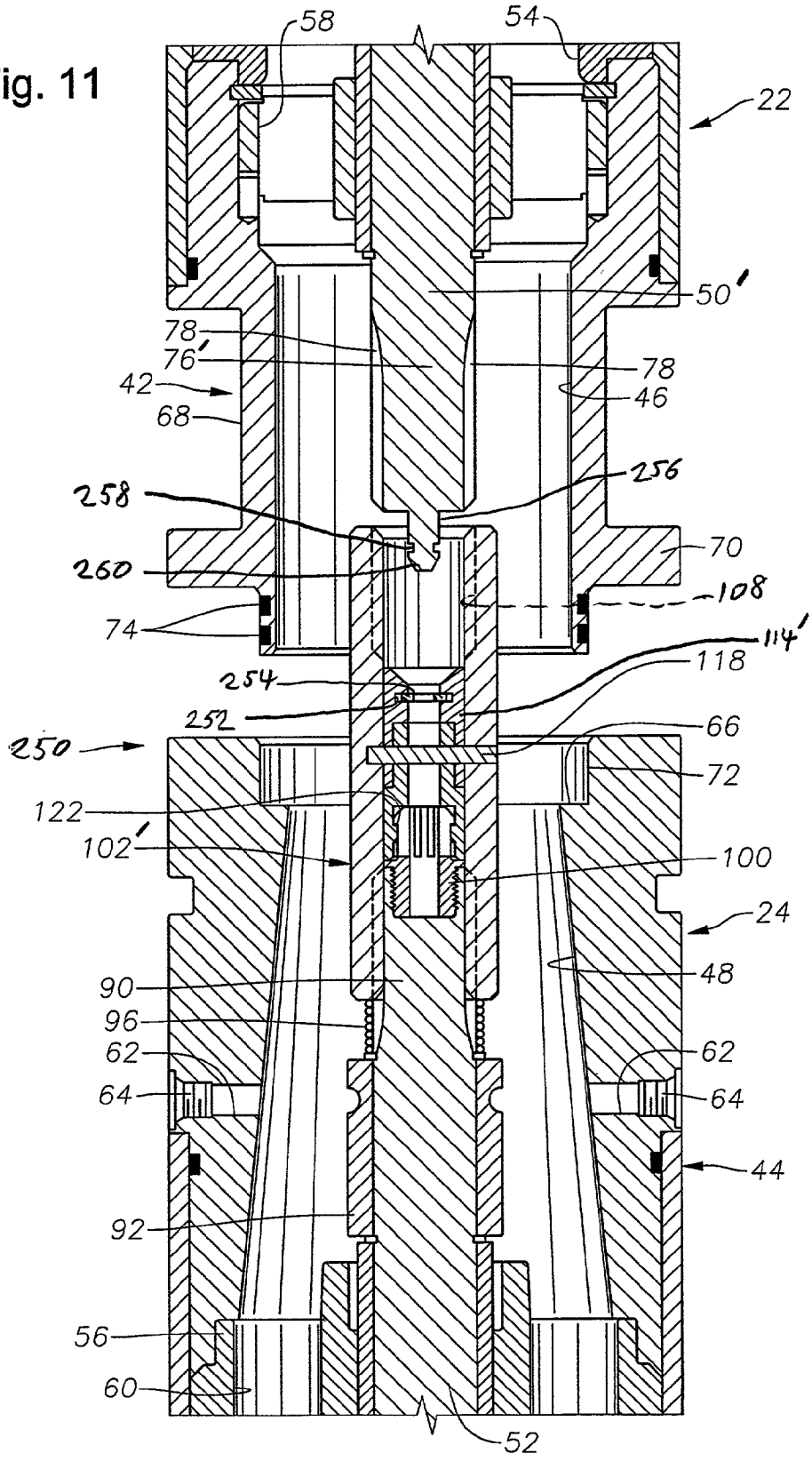

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Fig. 12

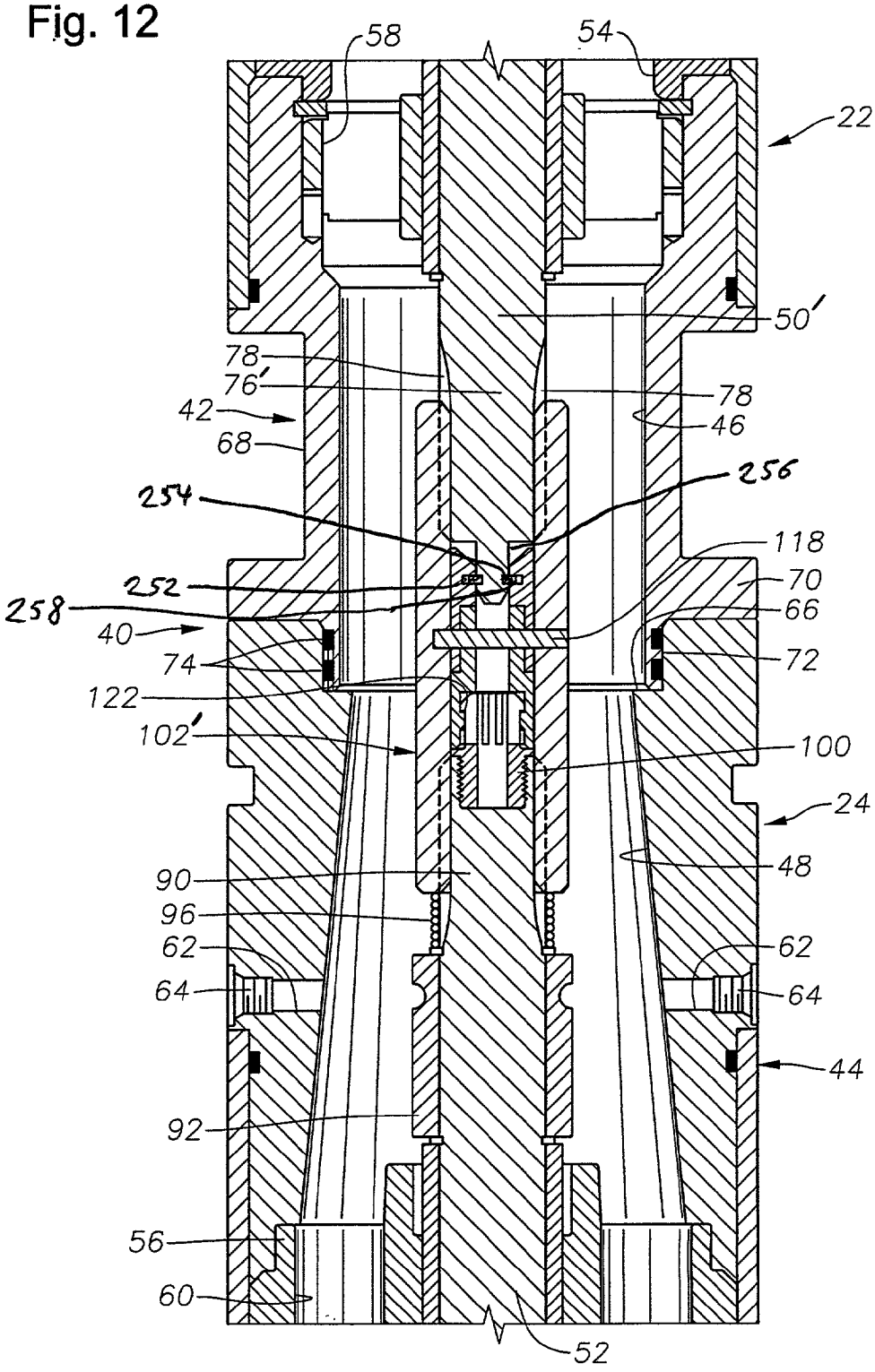
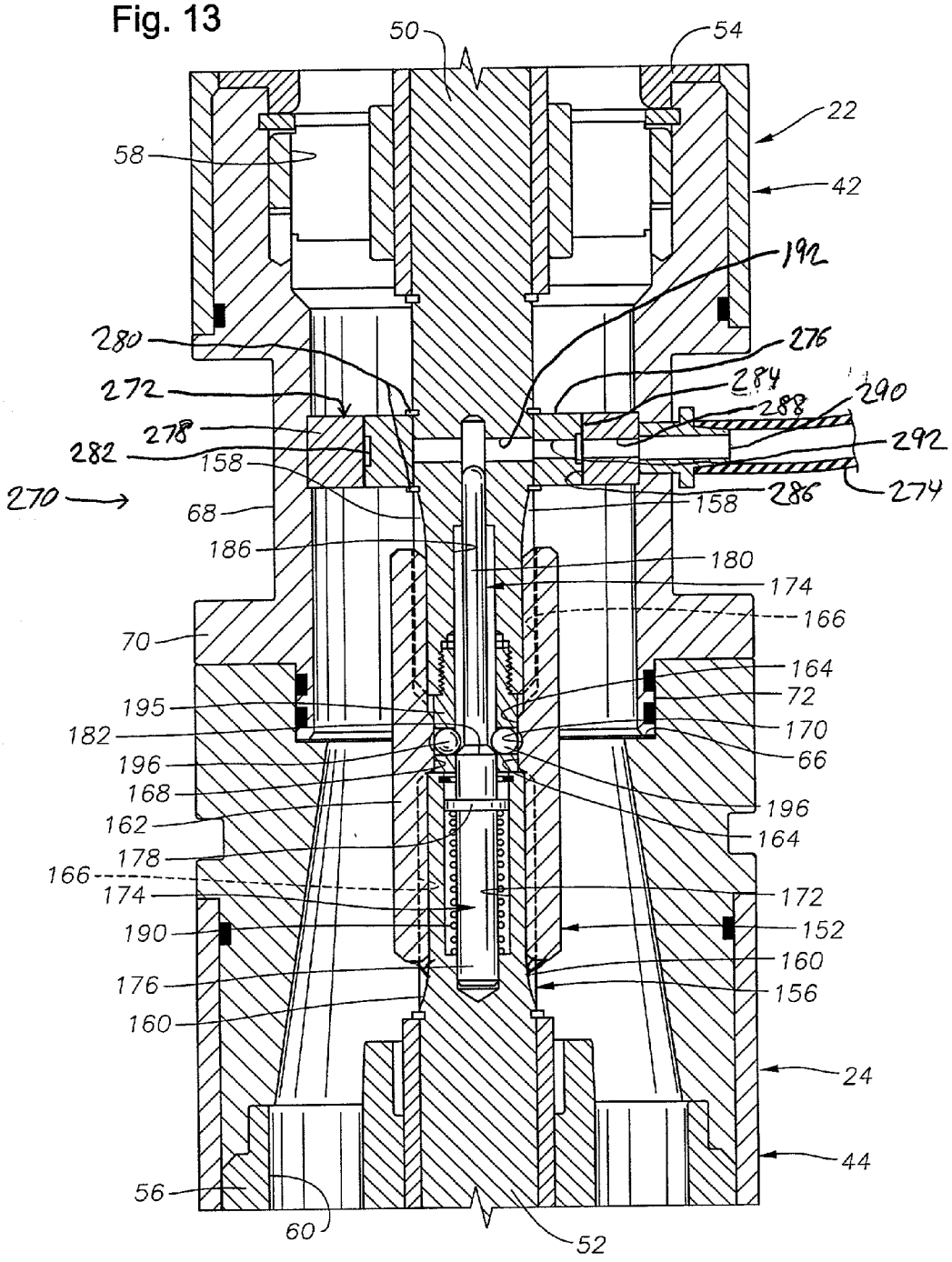

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Fig. 13


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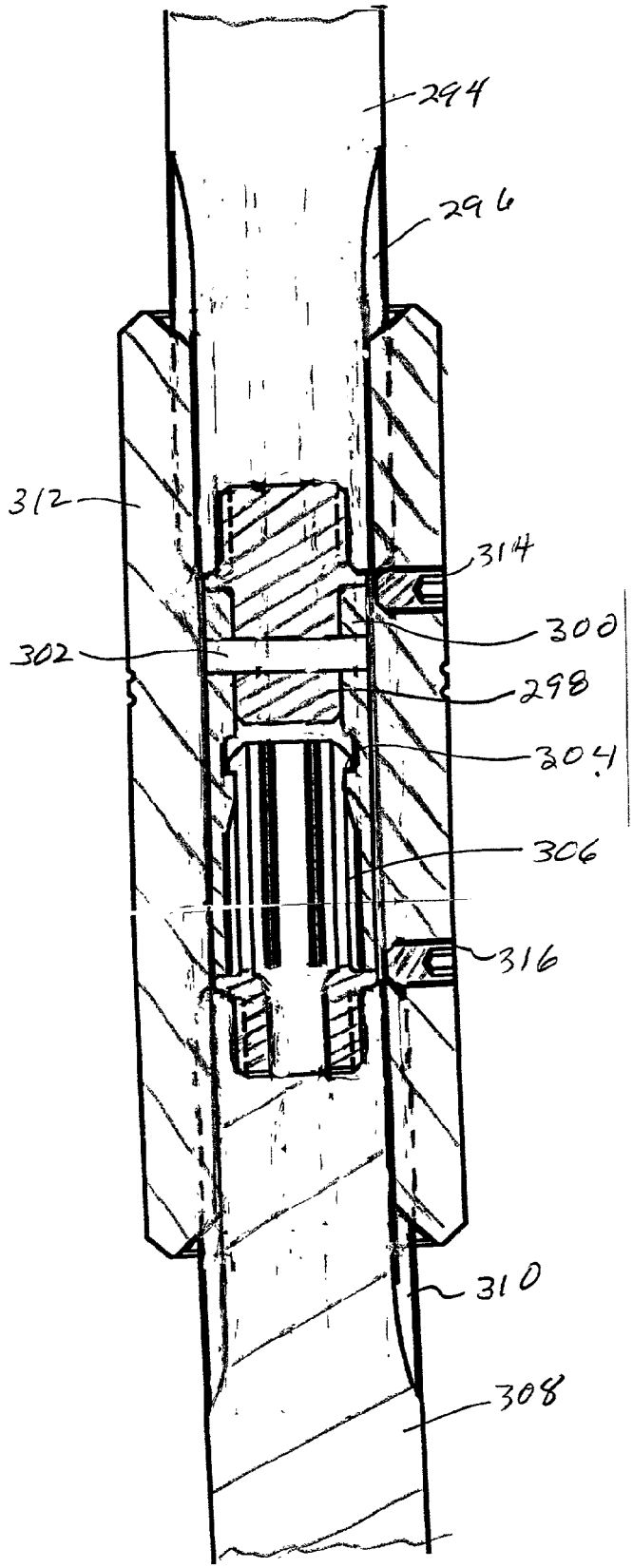


FIG. 14

SHAFT LOCKING COUPLINGS FOR SUBMERSIBLE PUMP ASSEMBLIES

[0001] This application claims the provisional filing date of Jun. 5, 2001, Ser. No. 60/296,014.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The invention relates to devices and techniques for coupling shafts and other portions of submersible pump assemblies and like components.

[0004] 2. Description of the Related Art

[0005] Conventionally, electrical submersible pump ("ESP") assemblies have been made up of a series of interconnectable modular sections including one or more pump sections with an associated fluid intake, a motor section and a seal section. Each of these sections includes an outer radial housing and a radially interior shaft. At present, the shafts and their connections are designed so that they can primarily transmit a compression load. The shaft of each section is interconnected with the shaft of the adjacent section by straight splining. There are normally no securing members used that would resist pulling apart of the shafts. Placement of the shafts or shaft connections under tension loads will cause the connection to separate easily.

[0006] This sort of "compression only" connection between shaft members is permissible when a standard ESP configuration is used wherein the pump section(s) are located above the seal and motor sections. Thrust bearings in the seal and motor sections support the pump sections, and the shaft members are not placed in tension. When a "bottom intake" ESP configuration is used, however, the pump section(s) are located below the motor and seal sections in the wellbore. An expensive thrust bearing is required to support the ESP components.

[0007] Although it might be possible to simply pin or weld the shafts of adjacent ESP sections together, there is an operational problem with doing so. In practice, it is difficult to assemble and disassemble the pinned shafts since they reside within the housings. If the connection is welded, it is quite difficult to disassemble the sections after removal of the pump assembly from the wellbore.

[0008] It would be desirable to have methods and devices that overcome the problems of the prior art.

SUMMARY OF THE INVENTION

[0009] The invention provides methods and devices for interconnection of components within an electrical submersible pump assembly and the like. This interconnection may be between a seal section and a motor section, a motor section and a pump section, a pump section and a seal section and so forth. The shaft sections are interconnected to support compression loading as well as a predetermined amount of tension loading.

[0010] In addition, the shaft interconnection is formed to be releasable in a selective manner. In one embodiment, the interconnection between the shaft sections is released when a predetermined amount of tension is applied to the connection. In a first embodiment a shear pin or other shearable member is ruptured by application of a predetermined amount of tension loading. In a second described embodiment, the interconnection between adjacent shaft sections is handled by spherical locking elements or balls. The locking elements are released by axial movement of an actuator. In a third embodiment, the shafts of adjacent components are provided with axially-directed intermeshing fingers on the shaft members to secure the shaft members to each other for transfer of torsional forces. A fourth exemplary embodiment employs a snap ring connection to fixedly secure adjacent shaft members to one another. A fifth embodiment is also described that is similar in many respects to the second embodiment. In this embodiment, fluid pressure is used to move the actuator. A sixth embodiment employs a hub carried by one shaft end, the hub having an axial load transmitting shoulder. A latch member with resilient fingers is secured to the other shaft end.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] **FIG. 1** is a side cross-sectional view of an exemplary electrical submersible pump assembly disposed within a well bore on production tubing.

[0012] **FIG. 2** is a partially exploded, side cross-sectional view of a first exemplary connection assembly used for interconnecting the two pumps in the pump assembly depicted in **FIG. 1**.

[0013] **FIG. 3** is a side cross-sectional view of the components depicted in **FIG. 2** with the adjacent shaft sections being moved toward interconnection with one another.

[0014] **FIG. 4** is a side cross-sectional view of the components shown in **FIGS. 2 and 3** with the pump components fully interconnected.

[0015] **FIG. 5** is a side cross-sectional view of the components shown in **FIGS. 2, 3** and **4** wherein the pump components have been separated.

[0016] **FIG. 6** is a side cross-sectional view of a second exemplary connection assembly used to interconnect the two pumps shown in **FIG. 1**. In this view, the pumps are fully interconnected.

[0017] **FIG. 7** is a side cross-sectional view of the connection assembly depicted in **FIG. 6** with the release mechanism partially actuated.

[0018] **FIG. 8** is a side cross-sectional view of the connection assembly depicted in **FIGS. 6 and 7** wherein the release mechanism is fully actuated.

[0019] **FIG. 9** is a side cross-sectional view of a third exemplary connection assembly that incorporates a connection for the shaft sections having a snap fastener with a crenelated torque transfer arrangement.

[0020] **FIG. 10** is a side cross-sectional view of the connection assembly shown in **FIG. 9** with the pump assemblies now interconnected with one another.

[0021] **FIG. 11** is a side cross-sectional view of a fourth exemplary connection assembly that incorporates a split ring shaft connection arrangement.

[0022] **FIG. 12** is a side cross-sectional view of the connection assembly shown in **FIG. 11** with the pump assemblies now interconnected with one another.

[0023] **FIG. 13** is a side cross-sectional view of a fifth exemplary connection assembly having an arrangement for hydraulic disconnection of the pump assemblies.

[0024] **FIG. 14** is a side cross-sectional view of a sixth exemplary connection assembly.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0025] **FIG. 1** represents an exemplary well bore **10** that has been drilled through earth **12** into a formation (not shown). The well bore **10** is a producing well and contains a string of production tubing, the lower end of which is shown at **14**. The production tubing has incorporated therein an electric submersible pump assembly, generally shown at **16**. The pump assembly **16** is made up of a series of interconnected modular sections. In this case, there are a motor section **18**, a seal section **20** and two pump sections **22, 24**. The ESP assembly **16** is a reverse, or bottom intake pump assembly since the pump sections **22, 24** are located downhole from the motor and seal sections **18, 20**. A fluid intake manifold **26** is interconnected to the lower pump section **24**. The motor section **18** has a power cable **30** which extends from the motor section **18** to the surface (not shown) of the well **10**.

[0026] **FIG. 2** is representative of an exemplary connection assembly **40** used to form the interconnection between the two pump sections **22, 24**. It should be understood, however, that the interconnection shown could also be that between the seal section **20** and the upper pump section **22** or the motor section **18** and the seal section **20**, as the same principles of interconnection would apply since each of the devices listed includes a radially outer housing or body and a rotatable shaft member contained radially there within. The upper pump section **22** and the lower pump section **24** have the same construction. As can be seen in **FIG. 2**, each pump section **22,24** includes a radially outer housing body **42, 44** that defines a longitudinal central chamber **46, 48** therein. A shaft member **50, 52** is secured by rotatable bearing **54, 56** within the central chamber **46** or **48** of each pump section **22, 24**. Fluid flow paths **58, 60** permit fluid to flow through each bearing **54, 56**. In each pump section **22, 24**, a pair of fluid ports is disposed through the housing body. Fluid ports **62** are shown in the housing body **44** of the lower pump **24**. These ports **62** are normally closed by caps **64**.

[0027] The upper end of the housing body for each pump section **22, 24** defines an annular landing shoulder **66**, one of which is shown on the lower pump section **24**. The lower end of each housing body **42, 44** includes a reduced diameter portion **68**, one of which is shown at the lower end of the upper pump section **22**. Radially enlarged annular flange **70** is located immediately below the reduced diameter portion **68**, while a reduced diameter seating portion **72** is located just beneath the flange **70**. Annular elastomeric seals **74** are disposed upon the seating portion **72**.

[0028] The upper shaft member **50** within the pump section **22** has a lower end portion **76** with a plurality of longitudinal splines **78** or the like formed therein. The lower end portion also defines an internally threaded blind bore **80** that retains a latching member **82** having external threads that engage the internal threading of the bore **80**. The latching member **82** has a cylindrical base **84** with a plurality of fingers **86** extend axially outward therefrom. The fingers **86** are maintained in a spaced relation from one another about the circumference of the base **84**. A radially outwardly projecting catch **88** is formed on the end of each finger **86**. The fingers **86** can be flexed radially inwardly to a slight degree.

[0029] The upper end **90** of the shaft member **52** in the lower pump section **24** is constructed similarly, although with a few differences. A collar **92** surrounds the upper end **90** below longitudinal splines **94**. Compressible spring **96** surrounds the upper end **90** proximate the splines **94**. A blind bore **98** defined in the end **90** retains a latching member **100** that is identical to the latching member **82** described earlier. As a result, like reference numerals are used to designate the fingers and catches associated therewith.

[0030] A coupling sleeve **102** is shown in **FIG. 2** apart from other components of the connection assembly **40**. The coupling sleeve **102** includes an elongated tubular body **104** that defines a elongate passage **106** therein. The passage **106** has longitudinal splines **108, 110** scribed into each end of the body **104**, the splines **108, 110** being complimentary in shape and size to interfit with the splines **78, 94**, respectively, of the opposing shaft members **50, 52**. A first inner hub member **112** and a second inner hub member **114** are disposed loosely within the passage **106** of the body **104**. The first inner hub member **112** has a reduced diameter axially protruding forward portion **116**. The second inner hub member **114** surrounds the protruding portion **116**. Shear pin **118** is disposed through the walls of both the second inner hub member **114** and the protruding portion **116** of the first inner hub member **112**, thereby securely interconnecting the two components. The shear pin **118** is a frangible member that is designed to fail (i.e., to shear) at a predetermined shear load. The first and second hub members **112, 114** each have internal annular shoulders **120, 122** that are shaped and sized to engage the catches **88** at the ends of the fingers **86** of each latching member **82, 100**.

[0031] **FIGS. 3 and 4** depict the assembly of an engaged interconnection of the two pump sections **22, 24** using the connection assembly **40**. In **FIG. 3**, the upper and lower pump sections **22, 24** have been axially aligned with one another and moved toward engagement by disposing the coupling sleeve **102** between the two pump sections **22, 24**, and the shaft ends **76, 90** are inserted into the opposite ends of the coupling sleeve **102**. As a result, the splines **78** become engaged with splines **108** in the coupling sleeve **102** while the splines **94** are engaged with the splines **110** on the coupling sleeve **102**. The upper pump housing **42** becomes securely seated upon the lower pump housing **44** as the seating portion **72** of the upper pump housing **42** is inserted into the landing shoulder **66** of the lower pump housing **44** (see **FIG. 4**). When this occurs, the elastomeric seals **74** are urged into sealing engagement with the shoulder **66**. Engagement of the two pump sections **22, 24** is complete when the catches **88** of the latching members **82, 100** become rinterengaged with the respective annular shoulder **120, 122** within the coupling sleeve **102**. The fingers **86** are deflected radially inwardly to permit this interengagement, which is typically accomplished in a snap-lock engagement manner.

[0032] The engagement of the pump section **22, 24** is secure in response to various types of loading. The engagement of the splines **78, 108** and **94, 110** permits rotational

torque to be transmitted between the shaft members **50, 52**. Compressive loads upon the outer housings **42, 44** are absorbed directly by the housings **42, 44** via the direct connection of the shoulder **66** and the seating portion **72**. Compressive loading of the shaft members **50, 52** is borne by the abutting relation between the ends **76, 90** of the shafts **50, 52** and the coupling sleeve **102**. Limited tensile loads, that is, tensile loading up to a predetermined amount, are also permissible and can be borne by the connection assembly **40**. Specifically, the interengagement of the latching members **82, 100** with the first and second hub members **112, 114** will support such tensile loading. In currently preferred embodiments, the connection assembly **40** is designed to support tension loads up to a desired amount. The amount of this predetermined load will vary in accordance with the type of pump components used as well as the well conditions.

[**0033**] The pump sections **22, 24** may be separated by applying a suitably high tensile load to the pump sections **22, 24** to separate them. A suitably high tensile load is one in excess of that required to shear the shear pin **118**. This tensile loading is preferably applied once the ESP assembly **16** has been removed from the wellbore **10**. Separation of the pump sections may be accomplished by clamping onto the lower pump section **24** and lifting up on the upper pump section **22** using a crane or other device able to generate sufficient pull to effect separation. When a predetermined excessive amount of tensile loading is applied to the shafts **50** and **52**, the shear pin **118** ruptures, as is shown in **FIG. 5**, thereby permitting the first and second hub members **112, 114** to separate from one another. The first hub member **112** is retained upon the end **90** of the shaft **52** while the second hub member **82** and the coupling sleeve **102** are retained upon the end **76** of the shaft **50**.

[**0034**] Referring now to **FIGS. 6, 7** and **8**, there is shown an alternative embodiment for a connection assembly **150**, which is constructed in accordance with the present invention and also shown interconnecting the two pump sections **22, 24**. The structures of the components used as between the two embodiments are similar and, therefore, like reference numerals are used for like components. The primary differences as between the two embodiments are found in the longitudinal ends of the shaft members **50, 52** and the coupling sleeve **152** which is used in place of the coupling sleeve **102** described previously.

[**0035**] The connection assembly **150** includes the coupling sleeve **152** as well as the ends **154, 156** of respective shafts **50, 52**, which are configured to be engaged with the coupling sleeve **152**. The end **154** of shaft **50** features a plurality of radial exterior, longitudinal splines **158** that have the same construction as the splines **78** described earlier. The end **156** of shaft **52** also is provided with splines **160**. In this embodiment, coupling sleeve **152** is affixed to shaft end **156**, such as by welding.

[**0036**] The coupling sleeve **152** has a tubular body **162** that defines a central axial passageway **164** therein. The passageway **164** has radially inwardly-directed splines **166** at each end that are shaped and sized to interfit with the splines **158, 160** of the shaft ends **154, 156** in order to permit transmission of torsional forces across the shafts **50, 52** and the coupling sleeve **152**. The axially central section **168** of the passageway **164** presents a reduced diameter and has an annular groove **170** inscribed within, which serves as an axial load transmitting shoulder.

[**0037**] The upper end **156** of the lower shaft member **52** has a blind bore-type lower chamber **172** that has been drilled in. A pin **174** is retained within the lower chamber **172** and axially moveable therein. The pin **174** features a base portion **176** with a enlarged annular flange **178** that projects radially outwardly. Above the base portion **176** is a reduced diameter portion **180**. A tapered shoulder **182** is defined between the base portion **176** and the reduced diameter portion **180**. The reduced diameter portion **180** extends upwardly into an upper chamber **186** and reduced diameter passage **188** that have been drilled into the end **154** of the shaft member **50**. A compressible spring **190** is located in the lower chamber **172** and engages the flange **178** so that the pin **174** is urged upwardly. Laterally drilled access holes **192** interconnect the passage **188** to the exterior of the shaft **50**. Access hole **194** is disposed through the housing **42** of the upper pump section **22**.

[**0038**] A carrier **195** is threadedly secured within the lower end **154** of the shaft **50**. A plurality of spherical locking balls **196** can be seen in **FIG. 5** retained within carrier **195**. The balls **196** also reside within the annular groove **170** of the passageway **164** while in the locked position. The balls **196** are retained within the groove **170** by the width of the enlarged base portion **176** of the pin **174**. The balls **196** prevent carrier **195** from being withdrawn from the coupling sleeve **152**. The reduced diameter portion **180** of the pin **174** may be engaged at its upper end by a set screw, or other longitudinal member inserted through the access hole **194** in the housing **42** and one of the access holes **192** in the shaft **50**.

[**0039**] In **FIG. 6**, the connection assembly **150** is shown in a fully engaged condition such that the shaft ends **154, 156** are securely affixed to the coupling sleeve **152**. Shaft end **156** is permanently affixed to the coupling sleeve **152** by welding the splined portions together. **FIG. 7** depicts the pin **174** after having been moved downwardly slightly by a set screw or other longitudinal member (not shown), thereby compressing the spring **190**. In **FIG. 7**, the locking balls **196** are aligned with the tapered shoulder **182** or reduced diameter portion **180** of the pin **174** so that they may move radially inwardly out of the groove **170** of the coupling sleeve **152**, thereby freeing the coupling sleeve **152** from the latching connection with the latching member **195**. In **FIG. 8**, the pin **174** is shown returned by the spring **190** to its upward position. However, the locking balls **196** are no longer within the outwardly protruding groove **170** and the shaft **50** maybe drawn upwardly away from the shaft **52** and the coupling sleeve **152**. It can be seen then that the locking balls **196** are moveable between a locked position wherein the balls **196** reside within the groove **170**, thereby securing the shaft members **50, 52** together, and an unlocked position wherein the balls **196** are permitted to move inwardly from the groove **170**, thereby permitting the shaft members **50, 52** to be drawn axially apart from one another.

[**0040**] Referring now to **FIGS. 9 and 10**, a further exemplary embodiment for a connection assembly **200** constructed in accordance with the present invention. **FIG. 9** shows two exemplary pump sections **22** and **24** apart from one another, while **FIG. 10** shows the two pump sections **22, 24** interconnected with one another. The outer housing

bodies **42** and **44** are constructed identically to the housing bodies **42**, **44** described earlier. Thus, like reference numerals are used. The connection assembly **200** has an upper shaft member **202** and a lower shaft member **204**. These shaft members have end portions **206** that are designed to interlock with one another so as to be fixed against rotation with respect to one another. As a result, the shaft end portions **206** are radially enlarged, and castellations or fingers **208**, **210** project axially from the shaft end portions **206**. The castellations **208** on shaft **202** are matingly engageable with the castellations **210** on shaft **204** so that, when engaged, the shafts **202**, **204** are secured against rotation with respect to one another.

[**0041**] The shafts **202**, **204** are also configured to be locked together as against tensional forces by moving the two shafts axially toward one another and urging them into a locking relation. The end portion **206** of the upper shaft **202** includes an axial neck **212** of narrow radius and an enlarged chamber **214** disposed immediately behind the neck **212**. The end portion **206** of the lower shaft **204** has a reduced diameter rod **216** that is centrally located and extends axially outwardly. The distal end **218** of the rod **216** carries a number of spring-biased, tapered catches **220**. The rod **216** is shaped and sized to fit within the neck **212** in a complimentary fashion. The catches **220** are spring biased in a radially outward position and can selectively withdraw radially into the rod **216** and be urged past the neck **212** where the spring-bias will cause them to radially expand. The catches **220** prevent the shafts **202**, **204** from being drawn apart axially under tension. Thus, it can be seen that the shafts **202**, **204** may be locked together axially and radially by being urged toward one another.

[**0042**] **FIGS. 11 and 12** depict a further embodiment of the invention that is similar in many respects to the embodiment depicted in **FIGS. 2 through 5**. The connection assembly **250** is similar in many respects to the connection assembly **40** described earlier and depicted in **FIGS. 2 through 5**. Like components are given like references numerals. Unlike the connection assembly **40**, the connection assembly **250** incorporates a split ring connection. Specifically, the second inner hub member **114'** of the coupling sleeve **102'** has been modified to provide an annular groove **252** that loosely retains a split ring **254** within. By virtue of being split, the split ring **254** is radially expandable under internal urging. The split ring **254** has shape memory so that the ring will return to its original shape after such urging.

[**0043**] The upper shaft member **50'** of the connection assembly **250** no longer has latching member **82** affixed within its lower end portion **76'**. Instead, a reduced diameter rod **256** protrudes axially from the lower end portion **76'**. The distal end of the rod **256** has an annular recessed groove **258** that lies proximally from a tapered tip **260**. Rod **256**, groove **258** and split ring **254** serve as the axial load transmitting shoulder and latching member.

[**0044**] The upper shaft member **50'** can be secured against axial and rotational movement with respect to the lower shaft member **52** by moving the two shaft members toward one another and causing the split ring connection to be made. The engagement of the splines **78**, **108** will prevents rotation of the upper shaft member **50'** with respect to the coupling sleeve **102'**. When the upper shaft member **50'** is moved downwardly into engagement with the coupling sleeve **102'**, the tapered tip **260** enters the split ring **254** and urges it to expand radially outwardly into the recess **252**. Further downward movement of the upper shaft member **50'** will bring the split ring **254** into alignment with the groove **258** of the inner hub member **114'**, as shown in **FIG. 12**. In this position, the shape memory causes the split ring **252** to retract to its original shape and partially reside within the annular groove **258** of the rod **256**. As **FIG. 12** illustrates, the split ring **252** also partially resides within the annular recess **252** of the inner hub member **114'** effectively locking the upper shaft member **50'**to the coupling sleeve **102'**. The coupling sleeve **102** is secured to the lower shaft member **52** in a manner previously described. As a result, the split ring connection of the connection assembly **250** permits a snap together connection that locks the shaft members **50'**, **52**, as well as the coupling sleeve **102'**, together rotationally and axially.

[**0045**] Turning now to **FIG. 13, a** further exemplary embodiment of a connection assembly **270** is depicted which is similar in many respects to the connection assembly **150** described with respect to FIGS. **6-8**. The connection assembly **270** is assembled in the same manner as the connection assembly **150**, and the shaft members **50**, **52** are secured axially and rotationally in the same manner in each embodiment. The connection assembly **270** differs from the connection assembly **150** in that the pin **174** is moved axially to free the coupling sleeve **152** and release the connection using fluid pressure. A fluid transfer assembly **272** is provided that permits pressurized fluid to be transmitted from hose **274** into passage **188**. Fluid pressure within the hose **274** may be externally regulated and increased when desired to urge the pin **174** downwardly, thereby releasing the connection in the manner previously described.

[**0046**] The fluid transfer assembly **272** includes an inner annular member **276** and an outer annular member **278**. The inner annular member **276** is securely affixed to the upper shaft member **50** using techniques known in the art, such as pinning. Locking rings **280** are used to assist securing of the inner annular member **276** to the shaft member **50**. As a result of being secured to the shaft member **50**, the inner annular member **276** will rotate with the shaft member **50** within the outer housing body **42**. The outer annular member **278** is affixed in a secure manner to the outer housing body **42** and, thus, will not rotate as the shaft **50** rotates within the housing body **42**. The inner annular member **276** has a circumferential groove **282** that is cut into the radially outer surface **284** of the inner annular member **276**. The outer surface **284** of the inner annular member **276** is a bearing surface and engages the radially inner surface **286** of the outer annular member **278** in a substantially fluid-tight relation on either axial side of the groove **282**. At the same time, however, the inner annular member **276** can rotate within the outer annular member **278**.

[**0047**] It can be seen that the outer annular member **278** has a radial fluid communication port **288** that is aligned with the fitting **290** for the fluid transmitting hose **274**. The inner annular member also has a radial fluid communication port **292** that can transmit fluid between the groove **282** and access hole **192** within the shaft member **50**.

[**0048**] In operation, the shaft member **50** may be released from the coupling sleeve **152** by transmitting increased fluid

pressure through the hose **274**. Pressurized fluid is transmitted through the fitting **290** and the outer annular member **278** via fluid port **288** to the groove **282**. From the groove **282**, the fluid is communicated through the port **292** to the access hole **192** of the shaft member **50**. Since the groove **282** is annular, the fluid residing within the groove **282** will always be able to find its way into the port **292** even if the shaft member **50** is rotating.

[**0049**] In the embodiment of **FIG. 14**, shaft **294** has axial splines **296**. A boss **298** is secured into a threaded hole in the end of shaft **294**. Boss **298** is a cylindrical rod that may have an outer diameter less than the end of shaft **294**. A tubular member or hub **300** slides over boss **298** and extends below. Hub **300** is secured to boss **298** by a shear pin **302** that extends transversely between them. Hub **300** has an internal axial load transmitting shoulder **304**.

[**0050**] A latch member **306** is mounted to shaft **308**. Latch member **306** is similar to latch member **82** of **FIG. 2**, having a plurality of inward-biased fingers, each having a catch that snaps over load shoulder **304**. Bringing shaft **294** and **308** toward each other in straight axial movement causes latch member **306** to snap into engagement with load shoulder **304**, locking shafts **294** and **308** together for transmitting axial tensile force.

[**0051**] A sleeve **312** is employed for transmitting radial forces between shafts **294** and **308**. Sleeve **312** has internal splines that mesh with splines **310** of shaft **308** and splines **296** of shaft **294**. Sleeve **312** need not be affixed to either of the shafts **294**, **308** since it does not transmit tensile forces. Preferably, a stop device is employed to prevent sleeve **312** from sliding downward to the lower end of splines **310** of shaft **308**, which is shown to be the lower shaft in the drawings. Shaft **294** could alternately be the lower shaft in a vertical application of the pump. A stop device may also be used to prevent sleeve **312** from sliding too far onto splines **296** of shaft **294**, in the case the pump is operated horizontally. The stop devices could be snap rings, protuberances or other similar devices, and are shown is this embodiment to be set screws **314** or **316**. Set screws **314**, **316** protrude slightly into the bore of sleeve **312** and contact the ends of shafts **294**, **308** to center sleeve **312** on shafts **294**, **308**. Set screws **314**,**316** are preset prior to inserting sleeve **312** over shaft **204** or **308** and do not need to be tightened against either shaft **294** or **308**.

[**0052**] The inventive methods and devices are advantageous in that they permit tensile loading of the components within an ESP assembly and, thus, permit construction and use of reverse, or inverted, assemblies wherein the pump section or sections are located downhole of the seal and motor sections. In some preferred embodiments, the inventive methods and devices also provide for selectively reversible interconnection of the pump component sections such that they may be readily separated when desired. Separation may be accomplished by, for example, shearing a frangible member, such as shear pin **118**, or by axially moving a pin, such as pin **174**.

[**0053**] While described in terms of its preferred embodiments, those of skill in the art will understand that many modifications and changes may be made while remaining within the scope of the invention.

What is claimed is:

1. A submersible pump assembly, comprising:

first and second modules that connect together, each of the modules having a central shaft and an outer housing;

a first shaft end on the shaft within the first module;

second shaft end on the shaft within the second module; and

a latch assembly having mating portions on each of the shaft ends that latches the first and second shaft ends together when the shaft ends and housings are brought into engagement with each other with straight axial movement, the latch assembly transmitting axial tensile forces from one of the shafts to the other and transmitting torque from one of the shafts to the other.

2. The submersible pump according to claim 1, wherein the latch assembly comprises:

a set of external splines on each shaft end;

a sleeve that has internal splines that slide into engagement with the external splines of both shaft ends to transmit torque;

a latch member mounted to one of the shaft ends; and

a load shoulder carried by the other of the shafts, the latch member snapping into engagement with the load shoulder upon straight axial movement of the shaft ends toward each other.

3. The submersible pump according to claim 1, wherein the latch assembly comprises:

a set of external splines on each shaft end;

a sleeve that has internal splines that slide into engagement with the external splines of both shaft ends to transmit torque;

a latch member mounted to one of the shaft ends;

a load shoulder member mounted within the sleeve, the latch member having a biased resilient retainer that snaps into engagement with the load shoulder member; and

a pin that extends transversely through the load shoulder member and the sleeve to retain the load shoulder member with the sleeve.

4. The submersible pump according to claim 1, wherein the latch assembly comprises:

a set of external splines on each shaft end;

a sleeve that has internal splines that slide into engagement with the external splines of both shaft ends to transmit torque, the sleeve having an internal annular recess;

a radially movable locking member mounted to one of the shafts for moving radially into and out of engagement with the recess; and

an actuator axially carried within the other of the shafts in engagement with the locking member, the actuator being axially movable between a locked position pushing the locking member radially into engagement with the recess in the sleeve and a released position, allow-

ing the locking member to retract out of engagement with the sleeve, the actuator being axially biased to the locked position.

5. The submersible pump according to claim 4, further comprising an access port extending through one of the shafts at an end of the actuator for providing access to push the actuator to the released position.

6. The submersible pump according to claim 4, further comprising:

an access port extending through one of the shafts at an end of the actuator; and

an annular manifold mounted between the housing and the shaft at the access port;

an inlet port leading through the housing to the manifold for applying fluid pressure to push the actuator to the released position.

7. The submersible pump according to claim 1, wherein the latch assembly comprises:

a set of castellations on each of the shaft ends for meshing engagement with each other to transmit torque;

a load shoulder carried by one of the shaft ends; and

a resilient retainer carried by the other of the shaft ends that snaps into engagement with the load shoulder when the shaft ends are brought into engagement with each other.

8. The submersible pump according to claim 1, wherein the latch assembly comprises:

a set of external splines on each shaft end;

a sleeve that has internal splines that slide into engagement with the external splines of both shaft ends to transmit torque;

a latch member mounted to one of the shaft ends, the latch member having a biased resilient retainer;

a tubular load shoulder member mounted to the other of the shaft ends for receiving the latch member, the load shoulder member having an internal shoulder that is engaged by the retainer; and

a shear member that secures the load shoulder member to the other of the shaft ends that is sheared by an excessive tensile force to release the shaft ends from each other.

9. An electrical submersible pump assembly comprising:

first and second modular component sections, each of the sections having an outer housing and an inner shaft member;

a coupling sleeve having a bore and disposed between the modular component sections and receiving therein the shaft member of each of the component sections, the bore of the coupling sleeve and the shaft members having mating radial load transmitting shoulders for transmitting torque;

an axial load transmitting shoulder affixed to the shaft member of the first modular component section and located in the bore of the coupling sleeve; and

a locking element carried by the shaft member of the second modular section that engages the axial load transmitting shoulder to secure the shaft members to one another for transferring axial tension from one of the shaft members to the other.

10. The assembly of claim 9 wherein the outer housings of the component sections are in an abutting relation for the transmittal of axially compressive forces.

12. The assembly of claim 9 wherein the locking member comprises:

a latch member having a plurality of axially extending fingers with catches that are shaped and sized to engage the axial load transmitting shoulder.

13. The assembly of claim 9 further comprising a hub member within the bore of the sleeve, the axial load transmitting shoulder being formed on the hub member; and

a shear member that retains the hub member to the shaft member of the first modular section, the shear member shearing upon sufficient tensile overpull to release the shaft members from each other.

14. The assembly of claim 9 wherein the locking member comprises a plurality of spherical locking balls that are selectively moveable into and out of a locked position with the axial load transmitting shoulder.

15. The assembly of claim **14** wherein the locking member further comprises an actuator disposed within one of the shaft members and axially moveable therein, the actuator being associated with the locking balls to move the balls out of the locked position when the actuator is moved axially.

16. The assembly of claim **15** wherein the actuator is axially biased toward a position wherein the locking balls are in the locked position.

17. The assembly of claim 9 wherein the load transmitting shoulder comprises:

a biased resilient retainer ring carried within a groove in the bore of the coupling sleeve; and the locking member comprises:

a rod having an external ledge thereon that is engaged by the retainer ring as the rod enters the retainer ring.

18. A connection assembly for a pair of submersible pump modules, each having a central shaft and an outer housing, the connection assembly comprising:

a first shaft end having at least one radial drive shoulder thereupon;

a second shaft end having at least one radial drive shoulder thereupon; and

a coupling sleeve having a bore and a radial drive shoulder within the bore that meshes with the radial drive shoulders of the first and second shaft ends to transmit torque;

a hub located within the bore, the hub having a passage with an axial load transmitting shoulder therein, the hub being affixed to the first shaft end; and

a latching member affixed to the second shaft end, the latching member that snaps into engagement with the axial load transmitting shoulder when the shaft ends are moved into engagement with each other.

19. The connection assembly of claim **18** further comprising a shear member that connects the hub with the first shaft end, wherein the latching member is selectively

released by applying an excessive amount of divergent tension to the shaft ends to shear the shear member.

20. The connection assembly of claim **18** wherein the latching member has a resiliently biased retainer portion that engages the axial load transmitting shoulder.

21. The connection assembly of claim **18**, further comprising:

a boss on the first shaft end, the hub sliding over the boss; and

a shear pin extending transversely through the boss and the hub, thereby affixing the hub to the fist shaft end.

22. The connection assembly of claim **18**, wherein the retainer portion of the latching member comprises a plurality of axially extending fingers with catches that are shaped and sized to engage the axial load transmitting shoulder.

23. A method of releasably connecting an adjacent pair of modular component sections within a pump assembly, each of the sections having a shaft and an outer housing member, the method comprising:

providing a latch assembly having mating portions on each of the shaft ends;

bringing the shafts of each of the component sections toward each other in straight axial movement, causing the mating portions of the latch assembly to latch into engagement with each other;

transmitting torque through the latch assembly; and

transmitting axial tensile forces from one of the shafts to the other through the latch assembly.

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